IAP9 Rec'd PCT/PTO 19 MAY 2006

Power autonomous electric tool set.

The present invention relates to the field of self-powered apparatuses and tools, more particularly power autonomous portable electric tools, and relates to a lithium-ion or polymer lithium battery-operated tool set of the aforementioned type.

In the present invention, "tool" generally means an apparatus or implement adapted to facilitate the physical work of an operator performing a task, or to perform said task while controlled by an operator. By "tool set" is meant a tool and its autonomous rechargeable electric energy source, and the means for supplying the latter.

The following tools, which have already been manufactured by the Applicant, can be cited: electronic pruning scissors for cutting fruit trees and vineyards, vegetable grafters and fruit picking tools.

Other tools, manufactured using similar techniques, can be cited in a non-limiting manner among tools of the aforementioned type, including: saws, lawnmowers, bush cutters, hedge cutters, impact spanners, pneumatic hammers.

These power portable electric tool sets essentially distinguish over comparable tools that are actuated by hydraulic, pneumatic, and electric power sources in that they are self-contained and independent of any external power source, which enables the operator to move freely. They also distinguish over self-contained heat engine-powered portable tools, by the lack of pollution, foul odors, vibrations and noise during use, as well as by their reliability of use.

Furthermore, it has been shown that the use of these tool sets provides an unprecedented comfort of use, due to their silent operation and their flexibility.

Such power autonomous portable electric tool sets generally include at least three distinct functional sub-units, namely, a first sub-unit forming an electric actuator and generating the mechanical operation of the tool, a second sub-unit forming an electric energy source and essentially including a rechargeable electrochemical battery, and a third sub-unit forming a charger capable of recharging the battery.

The advent and development of these tool sets are mainly linked to two technical factors:

- The commercial availability of new types of batteries having a better capacity to weight ratio, on the one hand; and
- the development of technologies producing high performance electric motors.

The batteries that are currently used in the aforementioned tool sets are of the nickel-cadmium type, or of the nickel-metal hydride type. They have an energy capacity of about 30 – 50 watt-hour per kilogram.

Knowing that an operator is allowed to carry a maximum of 4 kg on his back, across his shoulder, or on his belt for work sustained throughout the day, in compliance with official guidelines, one can infer that with the current techniques using nickel-cadmium and nickel-metal hydride, the total capacity of the battery carried by the operator is between 120 and 200 watt-hours.

This capacity is not always sufficient to provide the power autonomous portable electric tool sets with the energy required to operate half day, let alone a full day.

Therefore, there is a need and an actual demand for batteries having a more efficient capacity to weight ratio, in order to expand the field of application of the power autonomous portable electric tool sets, in view of their aforementioned advantages and qualities.

To this end, the invention aims at using the emerging technology of lithium-ion and lithium polymer batteries in the context of power autonomous portable electric tools.

Indeed, although these batteries are now frequently used in mobile telephones, video cameras, and portable computers, they are not yet used in applications to portable electric tools, especially professional grade tools, due to difficulties encountered with their implementation in application requiring a lot of power and autonomy. However, they currently offer capacity to weight ratios of 150 – 220 watt-hours per kilo, which would triple, or even quadruple the power or operating time of these portable electric tools, compared to their current capabilities when used with nickel cadmium or nickel metal hydride batteries.

It should be noted that due to the power requirements, the use of lithium-ion and lithium polymer batteries in power portable electric tools requires high voltages.

Indeed, the lithium-ion and lithium polymer elements cannot naturally deliver too high a current and therefore require the base elements to be serially coupled so as to obtain high voltages, thereby making it possible to supply adequate voltages, in spite of a limited current.

Thus, to form batteries that deliver electric power adapted to applications to power autonomous portable electric tools, while complying with the laws in force governing serviceable voltages and providing useful working voltages, it is necessary to serially couple numerous elements or numerous cells, each of these cells grouping such elements in parallel.

By "element" is meant an individual electric energy accumulator. The lithium-ion or lithium polymer base elements are industrially manufactured according to standardized formats adapted to the applications. They are produced in bulk, at very competitive costs. Advantageously, but in a non-limiting manner, the elements of the lithium-ion battery of the second sub-unit described hereinafter are in the commercial 18650 size that offers the best capacity to cost ratio. As a general rule, these elements are equipped with internal safety mechanisms which enable high capacity batteries to be used safely.

As a result, there are substantial difficulties in controlling and/or managing such multi-component batteries, which have yet to be resolved.

Indeed, in the aforementioned applications (mobile telephones, video cameras, and portable computers), the batteries generally comprise at the most four serially associated elements or cells, the control of which, when charging and discharging, is not complex and is relatively easy to implement.

The object of the present invention is to find a solution to the aforementioned problem.

To this end, the present invention relates to a power autonomous portable electric tool set of the aforementioned type, i.e., which comprises at least the three functional sub-units mentioned previously, said tool set being characterized in that the first sub-unit is connected to the second sub-unit, at least during use of the tool, by a flexible electric cord, on the one hand, and in

that the power supply of the actuator that constitutes it can be cutoff automatically and/or at will by the operator, on the other hand,

the second sub-unit is portable and comprises a lithium-ion or lithium polymer battery formed by association of a series of cells, each cell comprising one element or a plurality of parallel elements, on the one hand, and one or a plurality of electric or electronic modules for controlling and/or managing the battery, these modules being located in the vicinity of said battery,

the third, charger sub-unit comprises at least one electric power supply, the voltage and current of which are adapted to recharging the lithium-ion or lithium polymer battery. This third sub-unit is electrically connected to the second sub-unit by a disconnectable flexible cord.

For the purpose of describing the claimed the invention, it is noted that "module" means a functional electric, electromechanic or electronic unit participating in the functions of the second sub-unit.

The present invention will be better understood from the following description, which relates to several preferred embodiments, provided by way of non-limiting examples and explained with reference to the annexed schematic drawings, in which:

Figure 1 is a perspective view of a tool set according to the invention, in the form of pruning scissors, during a charging phase.

Figure 2 is a perspective view of the tool set of Figure 1, during use by an operator.

Figure 3 is a synoptic diagram of a non-limiting embodiment of the tool in which the first sub-unit is equipped with a device for the automatic cutoff, at minimum low voltage, of its electric supply coming from the second sub-unit to which it is connected during use of the tool.

Figure 4 is a synoptic diagram of a non-limiting embodiment of the tool in which the second sub-unit is equipped with a module for the automatic cutoff, at minimum low voltage, of the electric supply of the first sub-unit to which it is connected during use of the tool.

Figure 5 is a synoptic diagram of a non-limiting embodiment of the tool, in which the second sub-unit is equipped with a module for the automatic

cutoff of the charging at maximum high voltage of its electric supply, the latter being connected to the third charging sub-unit.

Figure 6 is a synoptic diagram of a non-limiting embodiment of the tool, in which the second sub-unit is equipped with a module for the automatic cutoff of the charging at low current of its electric supply, the latter being connected to the third charging sub-unit.

Figure 7 is a synoptic diagram of a non-limiting embodiment of the tool, in which the third charger sub-unit is equipped with a device for the automatic cutoff of the charging at maximum high voltage of the electric supply of the second sub-unit.

Figure 8 is a synoptic diagram of a non-limiting embodiment of the tool, in which the third charger sub-unit is equipped with a device for the automatic cutoff of the charging at minimum low current of the electric supply of the second sub-unit.

Figure 9 is a synoptic diagram of a non-limiting embodiment of the tool, in which the second sub-unit is equipped with one or several modules capable of carrying out the following functions: a) the cutoff at minimum low voltage of the electric supply of the first sub-unit, when the first sub-unit is used by the operator; b) the automatic cutoff of the charging at maximum high voltage and, c) the automatic cutoff of the charging at minimum low current when the second sub-unit is connected to the third sub-unit during the charging operation; d) protection against short circuits; e) placing the battery in no consumption or very little consumption mode when the first sub-unit is not in use; f) stopping the charging at excessive temperature.

Figure 10 is a synoptic diagram of the second functional sub-unit that is integral with the tool set.

Figure 11 is an electronic skeleton diagram of some constituent elements of the second sub-unit shown in Figure 10.

Figure 12 is the schematic algorithm of one particularly efficient charging method.

As shown in Figures 1 and 2, the power autonomous portable electric tool set 1 includes at least three distinct functional sub-units 2, 3, and 4, namely, a first sub-unit 2 forming an electric actuator and generating the

mechanical operation of the tool, a second sub-unit 3 forming the electric energy source and essentially including a rechargeable lithium-ion or lithium polymer battery 5, and a third sub-unit 4 forming a charger capable of recharging the battery 5.

According to the invention, the first sub-unit 2 is connected to the second sub-unit 3, at least during use of the tool, by a flexible electric cord 6, on the one hand, and it is provided with a cutoff mechanism that makes it possible to disconnect the electric supply of the actuator 7 which constitutes it, automatically and/or at will by the operator, on the other hand.

The electric actuator of the first sub-unit 2 can be constituted, for example, by a direct current brush electric motor, or by a tri-phase synchronous brushless electric motor, with position sensors, or by a tri-phase synchronous brushless electric motor without position sensors.

The second sub-unit 3 can be carried by the operator, and it is constituted by a lithium-ion or lithium polymer electrochemical battery 5 formed by serially associating cells 8, each cell comprising one element or a plurality of elements 9 associated in parallel, on the one hand, and one or a plurality of electric or electronic modules for controlling and/or managing the battery, these modules being located in the vicinity of said battery, on the other hand. For example, they are fixed on the support of the battery and within the casing enclosing the second sub-unit 3. The can also be incorporated directly into the casing of the second sub-unit 3, for example, by wedging.

By positioning the module(s) in the immediate proximity of the battery 5, the connections and wiring are made easier and less fragile, and the measuring and control signals are less exposed to disturbances, losses or interferences and less subject to drifts, due to a reduced transmission distance.

According to advantageous embodiments of the invention:

- one module among the electric or electronic module(s) for controlling and/or managing the battery equipping the second sub-unit is configured for the function of automatically cutting off the electric supply of the first sub-unit when the battery voltage has reached a minimum low level prior to the deterioration, by significant loss of capacity and increase of

spontaneous discharge, of the lithium-ion or lithium polymer battery equipping the second sub-unit;

- one module among the electric or electronic module(s) for controlling and/or managing the battery equipping the second sub-unit is configured for the function of automatically cutting off the electric charging of the battery when the voltage delivered by the third charger sub-unit, to which it is connected, has reached the maximum value prior to the deterioration, by significant loss of capacity and increase of spontaneous discharge, of the lithium-ion or lithium polymer battery equipping the second sub-unit;
- one module among the electric or electronic module(s) for controlling and/or managing the battery equipping the second sub-unit is configured to carry out the function of automatically cutting off the electric charging of the battery when the current charging the battery has reached a minimum low level recommended or required by the manufacture of the lithium-ion or lithium polymer battery equipping the second sub-unit.
- one module among the electric or electronic module(s) for controlling and/or managing the battery equipping the second sub-unit is configured to carry out the function of protecting the battery against short circuits.

The third charger sub-unit 4 comprises at least one electric energy source, in which the voltage and current are adapted to recharging the lithium-ion or lithium polymer battery 5. This third sub-unit is electrically connected to the second sub-unit by a disconnectable flexible cord 10.

The second and third sub-units 3 and 4 can be in the form of a single unit integrating the two sub-units 3 and 4, or in the form of two distinct physical entities that are electrically connected to one another by a disconnectable flexible cord during the charging phases. This latter alternative embodiment is naturally preferred in the context of the present application for reducing the load to be carried by the operator.

The electric flexible cord 6 that connects the first sub-unit 2 to the second sub-unit 3 can be provided with:

- a connector 24 toward the second sub-unit 3; or
- a connector 25 toward the first sub-unit 2; or
- a connector 25 toward the first sub-unit 2 and also a second connector 24 toward the second sub-unit 3.

According to a first non-limiting embodiment of the invention (Figure 3), the first sub-unit 2 is equipped with a device for the automatic cutoff, at minimum low voltage, of its electric supply coming from the second sub-unit 3 to which it is connected during use of the tool. It should be reminded that lithium-ion or lithium polymer batteries should never be completely discharged; a mere discharge below the minimum voltage value recommended by the manufacturer leads irremediably to the deterioration of the battery. Therefore, it is necessary to equip the tool set with a device limiting the discharge voltage to remedy this drawback. The precision of this minimum discharge voltage limitation should be on the order of 10%. It is obtained by means of an electronic system based on a voltage comparator 11, preferably with hysteresis, that compares the voltage of the battery to a reference voltage, which is determined by the multiplication of minimum discharge voltage of an element recommended by the manufacturers of lithium-ion or lithium polymer battery elements by the number of battery cells in a series. This system thus enables the cutoff of the electric supply of the first sub-unit by acting directly on a cutoff member, for example, a Mos transistor or a relay 12. This device can be located directly on the first sub-unit, which is the case for this first embodiment, but also on the second sub-unit, which corresponds to the next example of embodiment.

According to a second embodiment (Figure 4), the battery discharge voltage limitation is obtained during use of the tool by one of the electric or electronic modules for controlling and/or managing the battery of the second sub-unit to which it is connected by the flexible cord 6 during use of the tool. The embodiment is identical to that described hereinabove, the difference being that the electronic cutoff system is located on the second sub-unit.

According to a third embodiment (Figure 5), the second sub-unit is equipped with a module for the automatic cutoff of the charging, at maximum high voltage, of its electric supply, the latter being connected to the third charger sub-unit 4. It should be reminded that lithium-ion or lithium polymer batteries should never be charged beyond a maximum voltage recommended or required by the manufacturer of the lithium-ion or lithium polymer battery used, as exceeding this charge voltage would irremediably lead to the deterioration of the battery elements. Therefore, it is necessary to equip the

tool set with a charge voltage limiting device in order to remedy this drawback. This maximum charge voltage limitation must be very precisely set to at least 1%; it is obtained by an electronic system constituted by a voltage comparator 13, preferably with hysteresis, that compares the battery voltage to a reference voltage, which is determined by the multiplication of the maximum charge voltage of an element as recommended by the manufacturer of the elements of the lithium-ion or lithium polymer battery that is used by the number of serially associated cells of the battery. This system thus enables the cutoff of the electric supply of the charging of the second sub-unit by acting directly on a cutoff member, for example, a Mos transistor or a relay 14. This embodiment requires an off-load voltage of the charger that is greater than the reference voltage. This device can be located directly on the second sub-unit 3, which is the case in this embodiment, but can also be mounted directly on the third charger sub-unit, as explained hereinafter.

According to a fourth embodiment (Figure 6), the second sub-unit is equipped with a module for the automatic cutoff of its electric supply at minimum charge current, the latter being connected to the third charger sub-unit 4. It should be reminded that the manufacturers of lithium-ion or lithium polymer battery elements recommend stopping the charging at a minimum current value, which prevents plating of the metallic lithium and the element from becoming unstable and dangerous, and thereby causing its deterioration. Consequently, it is necessary to equip the tool set with a device for limiting the charging at minimum current. This limitation at minimum charge current is obtained by a current comparing electronic system 15 constituted by a current comparator, preferably with memory, that compares, via a shunt or a current sensor 16, the battery charging current to a reference current, which is determined by the multiplication of the end of charging current recommended by the manufacturer of the lithium-ion or lithium polymer battery elements used by the number of associated parallel elements constituting the cells of the battery. This system thus enables the cutoff of the electric supply of the charging of the second sub-unit 3 by acting directly on a cutoff member, for example, a Mos transistor or a relay 17. To carry out this function, this module can be located directly on the second sub-unit, which is the case in

this embodiment, but can also be directly mounted on the third charger sub-unit 4, as explained in another embodiment disclosed hereinafter.

According to a fifth embodiment (Figure 7), it is the third charger sub-unit 4 that implements the limitation at maximum charge voltage by cutting off the electric supply of the second sub-unit 3 to which it is connected during the charging operation. This embodiment is identical to that described hereinabove, the difference being that the electronic cutoff system is located on the third charger sub-unit 4.

According to a sixth embodiment (Figure 8), it is the third charger sub-unit 4 that implements the limitation at minimum charging current by cutting off the electric supply of the second sub-unit 3 to which it is connected during the charging operation. This embodiment is identical to that described hereinabove, the difference being that the electronic cutoff system is located on the third charger sub-unit 4.

These two last embodiments are integrated into the third charger sub-unit 4 that transforms the alternating electric energy of the network into direct, pulsating or rectified voltage and current, adapted to recharging the lithium-ion or lithium polymer battery, when the third charger sub-unit 4 is electrically connected to the second sub-unit 3 by a flexible cord. The third charger sub-unit 4 is electrically connected by a disconnectable flexible cord 10 to the second sub-unit 3, for example, by means of a connector 23.

To make an operational and reliable tool set, according to a seventh embodiment (Figure 9), some of the six previously described embodiments will be allowed to cohabit, in order to obtain the control and/or management of the battery in limiting the discharge voltage and in limiting of charge voltage and current. Concurrently with these limitations, it will be necessary to provide protection against the battery short circuits that could cause ill-timed heating and cause the battery to catch fire. This protection against short circuits can be usefully obtained by a fuse or a circuit breaker 18, or a similar component, mounted on at least one terminal of the battery, preferably prior to any other connection. Furthermore, it is very important that the battery be placed in no consumption or very little consumption mode, in order to prevent the battery voltage from dropping below the minimum voltage beyond which the battery would deteriorate. This function can be carried out in a non-

limiting manner by a switch 19 arranged at one of the terminals of the battery, and preferably after the fuse or the breaker 18, if the latter are installed. The manufacturers of lithium-ion or lithium polymer battery elements also recommend that, during charging and discharging, the battery be protected against usage and recharging outside of certain temperature ranges. The temperature range recommended for use during discharging is between -15°C and +60°C, and between 0°C and 45 °C for charging. The risks of exceeding the thresholds are especially sensitive during charging and less sensitive during discharging. It is therefore necessary to protect the battery to a minimum during charging. To carry out this function, one could, in a non-limiting manner, insert a temperature sensor 20 capable of electrically isolating the lithium-ion or lithium polymer battery on a terminal of the battery, in the vicinity of the fuse. It must be noted that the limitation at minimum charging current can be replaced by a system limiting the charging duration in time, as a function of the capacity of the elements, of the number of associated parallel elements in a cell of the battery and of the maximum current delivered by the charger.

According to an eighth, non-limiting and extremely efficient embodiment (Figures 10, 11, 12) of the invention that has enabled the applicant to very safely obtain a cycle life of more than 1000 charging and discharging cycles, with a loss of capacity of less than 20%, over several years of testing; knowing that lithium-ion batteries are known for their risk of catching fire in view of their organic electrolyte and the very flammable lithium. In this embodiment, the second sub-unit 3 is equipped with a single module for controlling and/or managing the battery; the latter is in the form of at least one electronic board and includes at least one digital processing unit 21, such as, for example, a microprocessor, a microcontroller, a digital signal processor, associated with a memory and with annexed digital and/or analog circuits capable, together, of performing some, and preferably all of the following tasks:

managing the charging
managing the discharging
balancing the charging of each cell 8,
evaluating and displaying the capacity of the battery 5,

protecting the battery 5 when discharging against excess current when the tool is being used,
managing the tool during the storing phases,
managing the alarms;
managing and transmitting the information collected,
managing the diagnostics

Performing these various tasks is initiated and directed by the digital processing unit 21, under the control of a program managing the functioning of the tool set 1, while taking into account the user's commands and the values of various parameters measured in the area of the second sub-unit 3, and possibly in the area of the first and/or third sub-unit(s) 2 and/or 4.

According to one or several characteristics of the invention, and in view of completing the tasks of managing the charging, managing the discharging, balancing the charging of each cell 8, evaluating and displaying the capacity of the battery 5, the control module 26 constantly exploits the voltage measuring values for each cell 8 composing the battery 5.

To this end, and as shown in Figures 10 and 11 of the attached drawings, the invention provides that for a battery 5 formed of serially associated n-cells 8, the voltage measuring values of each cell 8 are furnished by an acquisition electronic chain 27 constituted mainly by identical analog n-modules 28 mounted at the terminals of the n-cellules 8, respectively, of the battery 5 and capable of measuring the voltage of the corresponding cell 8, respectively; the values of the voltages measured by each of the n-modules 28 being then directed, one after the other, via at least one analog multiplexer 29 and after amplification by an adapted circuit 30, toward an input analog/digital converter 21' of the digital processing unit 21 of the controlling and/or managing module 26.

The converter 21' can be either integrated into the unit 21, or can form a circuit separated from the latter.

By means of this acquisition electronic chain 27, the control module 26 performs a sequential or cyclical check of the voltages of the various cells 8, causing a high frequency refresh of the voltage data for each cell 8 available

in the area of the unit 21, thus making it possible to quickly take into account and react in the case of an abnormal voltage measuring value.

As shown in Figure 11 of the annexed drawings, the analog sub-modules 28 for measuring voltages perform a subtraction for each cell 8, respectively, between the voltage measured at its positive terminal and the voltage measured at its negative terminal, by means of a differential electronic circuit with operational amplifier 28' using resistances 28" or input resistive elements.

In order to achieve a measuring sensitivity adapted to a reliable and precise control of each cell 8, the differential electronic circuit with operational amplifier 28' of each voltage measuring sub-module 28 comprises resistances or input resistive elements 28" having an impedance close to or greater than 1 Mohm, so as to obtain very low leakage currents which, by way of non-limiting example, are less than 1/20000th per hour of the total capacity of the battery 5, the voltage measuring values of each cell 8 being preferably delivered with a measuring precision of at least 50 mV.

Advantageously, the measuring precision of the desired voltage, i.e., advantageous by at least 50 mV, is obtained by calibration during the manufacture of the electronic board of the module 26 for controlling and managing the battery, making it possible to individually compensate for the errors in measuring analog voltage 28.

For each voltage measuring module 28, for example, this calibration can involve programmatically inputting error correcting parameters in the digital processing unit 21, as a function of the measurement of one or several very precise reference voltages which, for this calibration operation, are substituted for the voltages that are normally measured at the terminals of each cell 8.

So that a measuring signal with the requisite precision can be delivered to the unit 28, the analog/digital converter 21' will output at least 10 data bits.

According to another characteristic of the invention, the task of balancing the charging of the cells 8 with respect to one another is managed by the digital processing unit 21 which, based on the voltage measuring values of each cell 8, and if necessary for each of them, controls the change

in the charging current by means of dissipating circuits using electronic switchers 31 associated with resistive elements 31'.

The method used to obtain a balanced charging of the battery 5 can be, for example, that described in the commonly owned French Patent No. 03 13570 filed by the Applicant on November 20, 2003.

According to another characteristic of the invention, the task of managing the discharging involves constantly checking the voltage data of each cell 8 by means of the digital processing unit 21, interrupting the discharging when the unit detects that one of these voltages of a cell 8 has reached the minimum discharge threshold recommended by the manufacturer of lithium-ion or lithium polymer elements, and cutting off the discharging by deactivating the discharge switching component 32, resulting in the tool 2 being stopped and, for example, in a non-limiting manner, by activating a sound or visual warning signal.

As shown in Figures 10 and 11 of the attached drawings, and according to another characteristic of the invention, the tasks of managing the charging, evaluating and displaying the capacity of the battery 5 and of protecting against excess current during the discharging are continuously managed by the digital processing unit 21 due to an analog electronic circuit 33 measuring the charge and discharge current of the battery 5.

Advantageously, during the task of managing the charging, while the third charger sub-unit 4 is connected to the second sub-unit 3 in the area of the electronic board of the module 20 for controlling and managing the battery 5, charging is ended by opening the charge switching component 34 that is controlled by the digital processing unit 21 when, by means of the analog electronic circuit 33 measuring the charging and discharging current, said unit 21 detects a drop of the charging current down to a recommended threshold, for example 50 mA, for the battery 5, on the one hand, or when the temperature of the battery 5 exceeds an authorized limiting value, for example 45°C, or yet when charging during for a period of time that is greater than a given fraction of the theoretical charging time, for example, about 20%.

Furthermore, the task of evaluating and displaying the capacity of the battery 5 is managed by the digital processing unit 21, the latter calculating said capacity by constantly taking into account, during charging and during

use of the tool, the information related to the instantaneous charging and discharging current of the battery 5 delivered by the analog electronic circuit 33 for measuring the charging and discharging current, on the one hand, and the voltage measuring values of each cell 8 and, not necessarily but for a more accurate calculation, their known average internal resistance.

The task of protecting against excess current during discharging of the battery 5 while the tool is being used, adapted to preserve the lithium-ion or lithium polymer battery from premature aging or from overheating, involves either cutting off the discharging current in the case of a very substantial pulsed overload of the maximum discharging current allowed for the battery 5, or of an excess of the maximum limiting temperature allowed for the latter, or limiting the discharging current as a function of the energy consumed by the tool during a certain sliding time period, knowing that the value of the energy and the sliding time period are experimentally predetermined as a function of the tool, its use and the cycle life desired for the lithium-ion or lithium polymer battery 5 of the second sub-unit 3.

According to a preferred alternative embodiment, the discharging current limitation is managed by the digital processing unit 21 by applying a pulse width modulation (PWM) control, generated either directly by said unit 21, or by a special component, through a control stage 35, to the discharge switching component 32 made, for example, in the form of an N-channel Mosfet type component.

In order to automatically achieve optimized storage conditions, one can provide that, when the electric tool set 1 is not being charged and has not been used for a given period of time, for example 10 days, the digital processing unit 21 automatically undertakes a storage managing task, which involves verifying whether or not the residual capacity of the battery 5 is greater than the storage capacity recommended by the manufacturers of lithium-ion or lithium polymer elements and, if the residual capacity is indeed greater than the storage capacity, having the digital processing unit 21 initiate an automatic discharge of the battery by means of resistive circuits 31' connected in parallel on each cell 8, until the storage capacity is reached, and, consequently, stopping all of the electronic circuits while placing the processing unit 21 in low consumption stand-by mode, and, if the capacity is

below the storage capacity, having the digital processing unit 21 set off a sound and/or visual alarm.

Advantageously, the digital processing unit 21 is capable of detecting the live connection of the charger 4 to the battery 5 by means of a voltage measurement carried out by the control and command module 26 at least at one of the terminals 37, preferably a positive terminal, of the second sub-unit 3 that are adapted to be connected to said charger 4.

By detecting the instant when at least one cell 8 has reached the minimum voltage recommended by the manufacturer, this function, possibly carried out by means of a particular adapted measuring circuit 36, makes it possible to initiate an automatic recharging of the battery 5, as long as the tool is stored in non-use phase.

When the controlling and/or managing module 26 detects an excessive or insufficient voltage of the charger 4 in the area of the corresponding connection terminals 37 of the second sub-unit 3, the digital processing unit 21 that uses this information orders the interruption of the charging and sets off a sound and/or visual alarm.

It is noted that the pair of terminals 37 for connecting to the charger 4 and the pair of terminals 37 for connecting to the tool 2 have a common negative terminal connected to the ground, but have distinct positive terminal, to each of which a corresponding switching component 32 or 34 is coupled.

To facilitate the long term control of the use of the tool set 1, as well as its maintenance and the planning of its technical follow-up, the task of managing the information and diagnostics can involve storing in the memory of the digital processing unit 21 information that is acquired during use of the tool, such as, for example, the number of recharges, the computation of the number of hours the tool was used, the change in the capacity of the battery 5 in time, the average energy consumed by the tool, or similar information; this information can be transmitted by means of a wire, radiofrequency, or infrared connection 40 toward a separate operating terminal, such as, for example a personal computer, an electronic personal assistant, GSM, which can possibly be connected to the Internet.

To optimize the integration of the means for controlling the tool set 1, the module 26 for controlling and/or managing the battery 5 of the second

sub-unit 3 forming a rechargeable electric energy source can be associated with an electronic module for controlling the actuator 2 and sensors thereof, for example, but in a non-limiting manner, on the same electronic board, using the same digital processing unit 21, if necessary, knowing that the electric actuator of the first sub-unit 2 can be constituted, for example, by a brush direct current electric motor, or by a brushless tri-phase synchronous motor with position sensors, or yet by a brushless tri-phase synchronous motor without position sensors.

The digital circuit 21 will also include a means for controlling the running of the program for managing the tool set 1 and for the sequenced acquisition of the measuring values, which is symbolically shown in Figure 12.

In order to provide additional security allowing to protect the cells 8 of the battery 5 when its cells are exposed to extreme voltage or current conditions, additional circuits for interrupting the connection of the second sub-unit 3 with the first or third sub-unit 2 or 4 can be provided, in parallel to the aforementioned normal controlling system constructed around the digital processing unit 21.

Thus, the electronic module 26 for controlling the battery 5 can comprise for each cell 8, redundant safety circuits 38 for stopping the charging, each of them being capable of individually controlling the general interruption of the charging, in the case of excess voltage in a cell 8, by directly deactivating the charge switching component 34 without biasing the digital processing unit 21.

Similarly, the electronic controlling and managing module 26 can comprise a discharge stopping redundant circuit 38' that is capable of ordering the interruption of the discharging if the measuring analog electronic circuit 33 detects a discharge current equal to or greater than a maximum value allowed for the battery 5, by directly deactivating the discharge switching component 32 without biasing the digital processing unit 21.

Preferably, the third charger sub-unit 4 adapted to recharging the lithium-ion or lithium polymer battery generates a voltage with a precision approximating 0.5% and a controlled current, both obtained by means of a

special circuit for regulating voltage and current. Such circuits are already known and do not need to be described any further.

As shown in Figures 1 and 2 of the annexed drawings, each functional sub-unit 2, 3, and 4 is mounted (when the sub-units 3 and 4 are distinct) in a specific protective and/or gripping casing, which can be connected to one another in pair by disconnectable flexible cables 6, 10 for transferring energy and transmitting the command and/or control signals between said sub-units 2, 3 and 4.

It is noted that the charging of the battery may or may not be carried out with the cable 6 connecting the sub-units 2 and 3 to each other.

The casing enclosing the first sub-unit 2 also carries the tool and is ergonomically configured, at least in the area of one portion, so as to enable an easy, reliable, and comfortable grip by the user.

Furthermore, the analog control buttons or members, as well as the sound and/or light display and warning means are preferably present, partially in the area of the casing of the first sub-unit 2 and partially in the area of the casing of the second sub-unit 3, as a function of their type and of the necessity for them to be accessible to the operator during actual use of the tool set 1.

Naturally, the invention is not limited to the embodiment described and shown in the annexed drawings. Modifications remain possible, in particular with respect to the constitution of the various elements, or by substitution of technical equivalents, without leaving the scope of protection of the invention.